eRD21 BACKGROUND SIMULATIONS

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- Personnel
- Introduction
- Accomplishments & Next Steps
- FY2020 Proposal

PERSONNEL

Red = Partial salary support by eRD21
Blue = Travel Support

- Vitaly Baturin (Old Dominion University)
- Pavel Degtiarenko (JLab)
- Latifa Elouadrhiri (JLab)
- Yulia Furletova (JLab)
- Charles Hyde (Old Dominion University)
- Kyungseon Joo (University of Connecticut)
- Andrey Kim (University of Connecticut)
- Alexander Kiselev (BNL)
- Vasiliy Morozov (JLab)

- Amethyst Maps (ODU)
- Nikolay Markov (UConn)
- Christoph Montag (BNL)
- Christine Ploen (ODU)
- Youri Sharabian (JLab)
- Marcy Stutzman (JLab)
- Mike Sullivan (SLAC)
- Mark Wiseman (JLab)

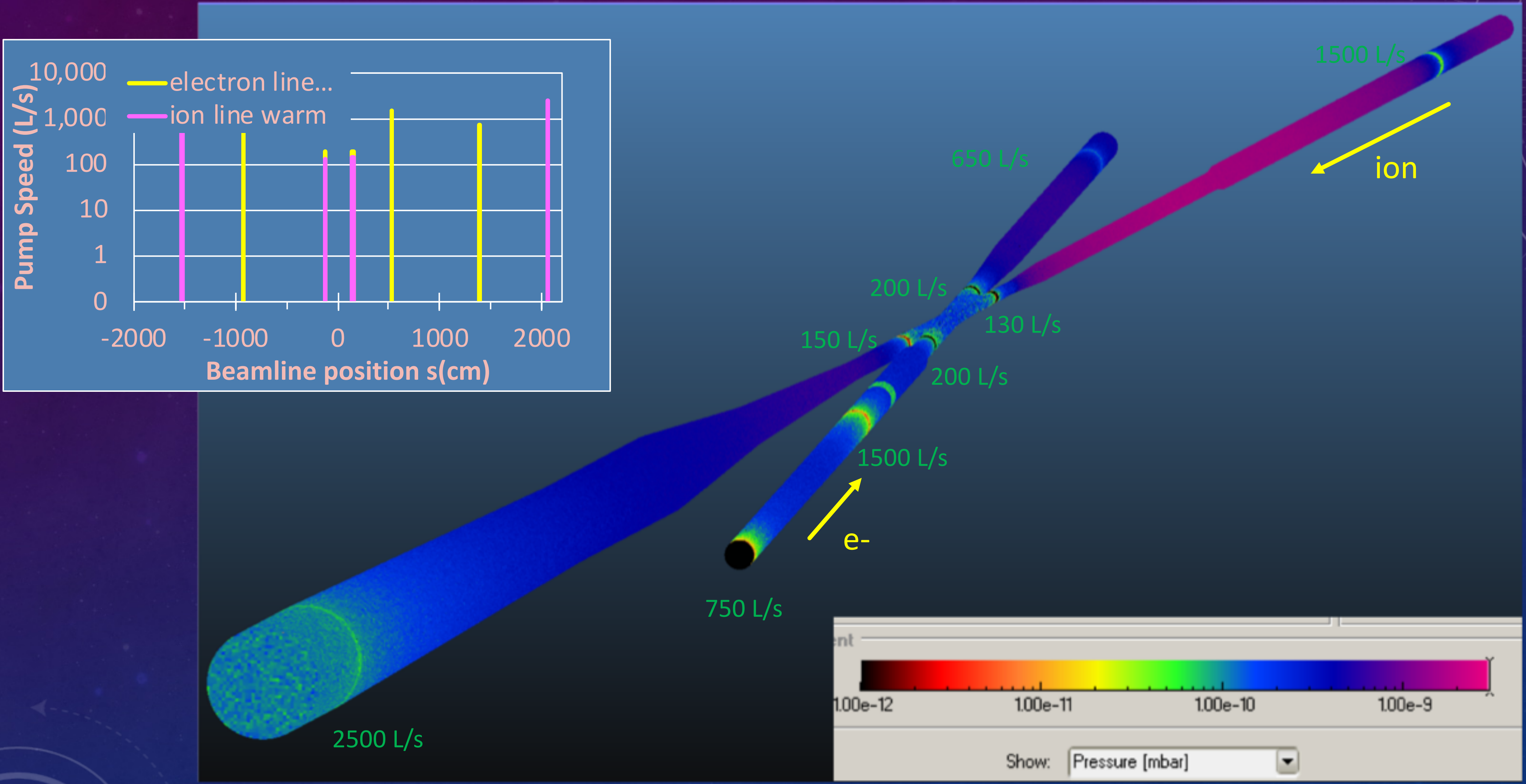
INTRODUCTION

- Detailed simulations of the EIC machine related backgrounds in the Interaction Region (IR) are crucial for proper design of the beam pipe, pumping system, detectors and front-end electronics
- Mitigating the backgrounds is an important aspect of the Machine-Detector Interface (MDI).

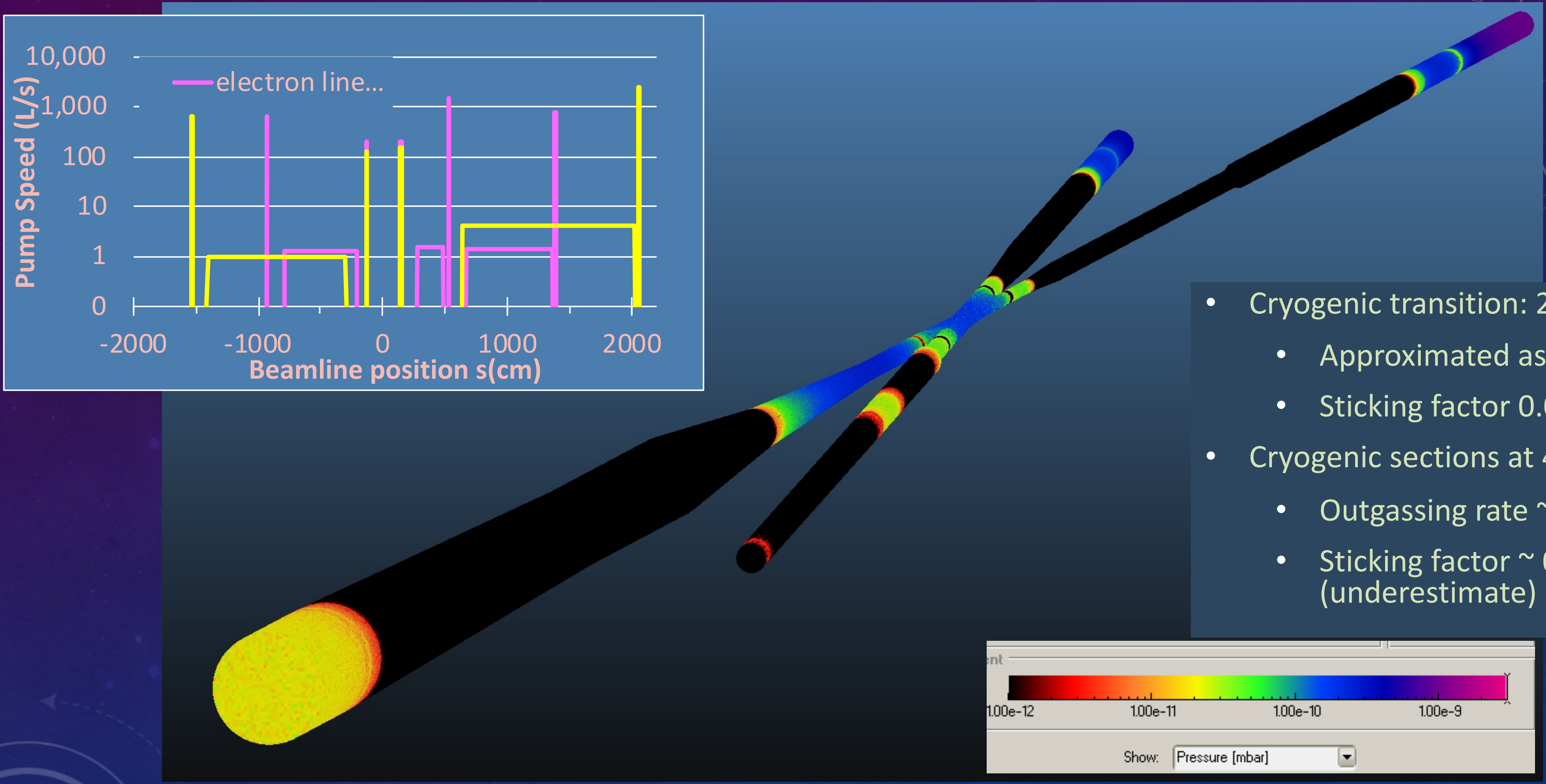
ACCOMPLISHMENTS AND NEXT STEPS IN FY19

- Vacuum Studies: New Beam Pipe
- Synchrotron Radiation
- Beam Gas Interactions
- Total Inclusive (physics) Rates
- Total Bremsstrahlung Rates
  - Tagged Bremsstrahlung
  - Tagged 0° (e,e’) scattering

VACUUM PROFILE, MAGNETS AT 298 K



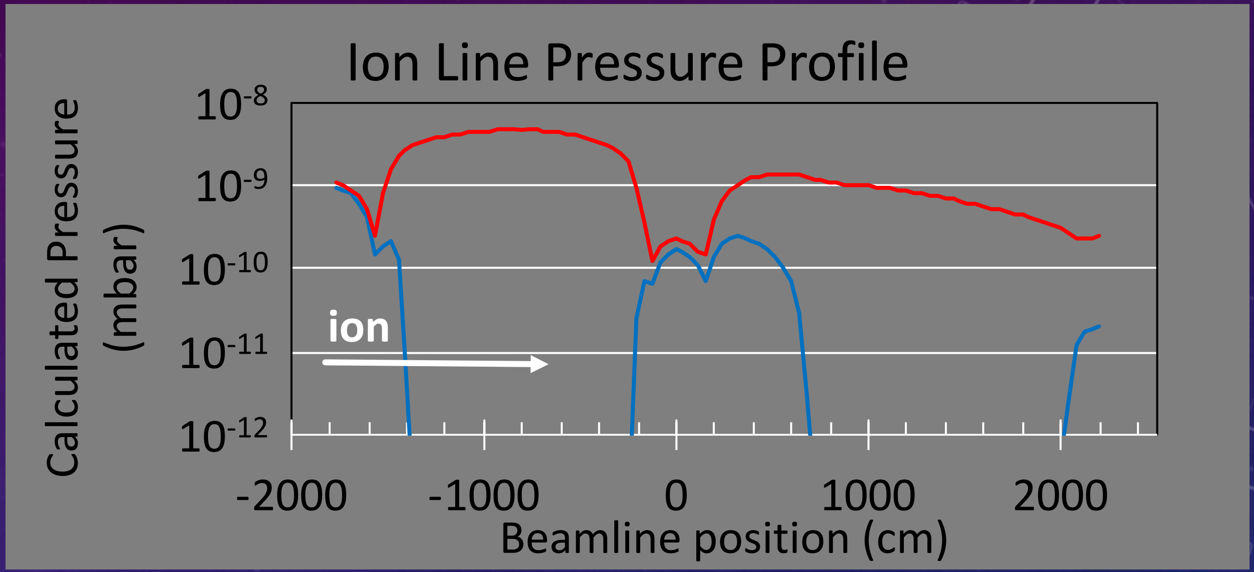
VACUUM PROFILE, MAGNETS AT 4 K

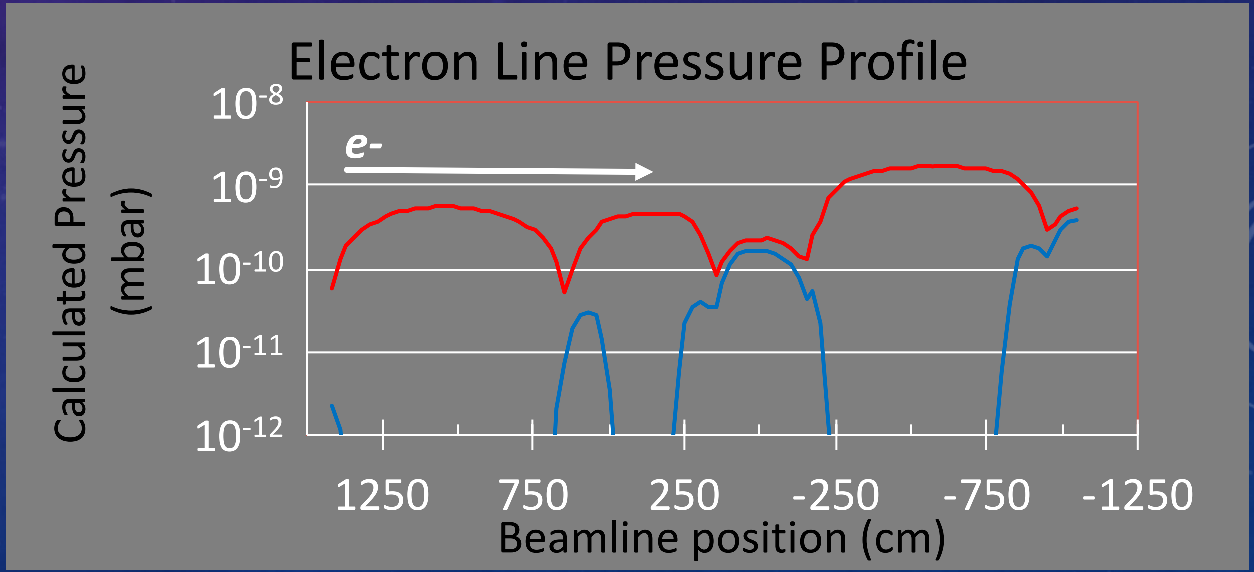


- Cryogenic transition: 293 to 4.5K
  - Approximated as 77 K
  - Sticking factor 0.01
- Cryogenic sections at 4.5K
  - Outgassing rate ~ 0
  - Sticking factor ~ 0.1 (underestimate)

VACUUM PROFILES

- Red: Magnets 298 K
- Blue: cold bore magnets (4 K).
- Realistic vacuum studies complete with Molflow
  - Required NEG pumping speeds identified



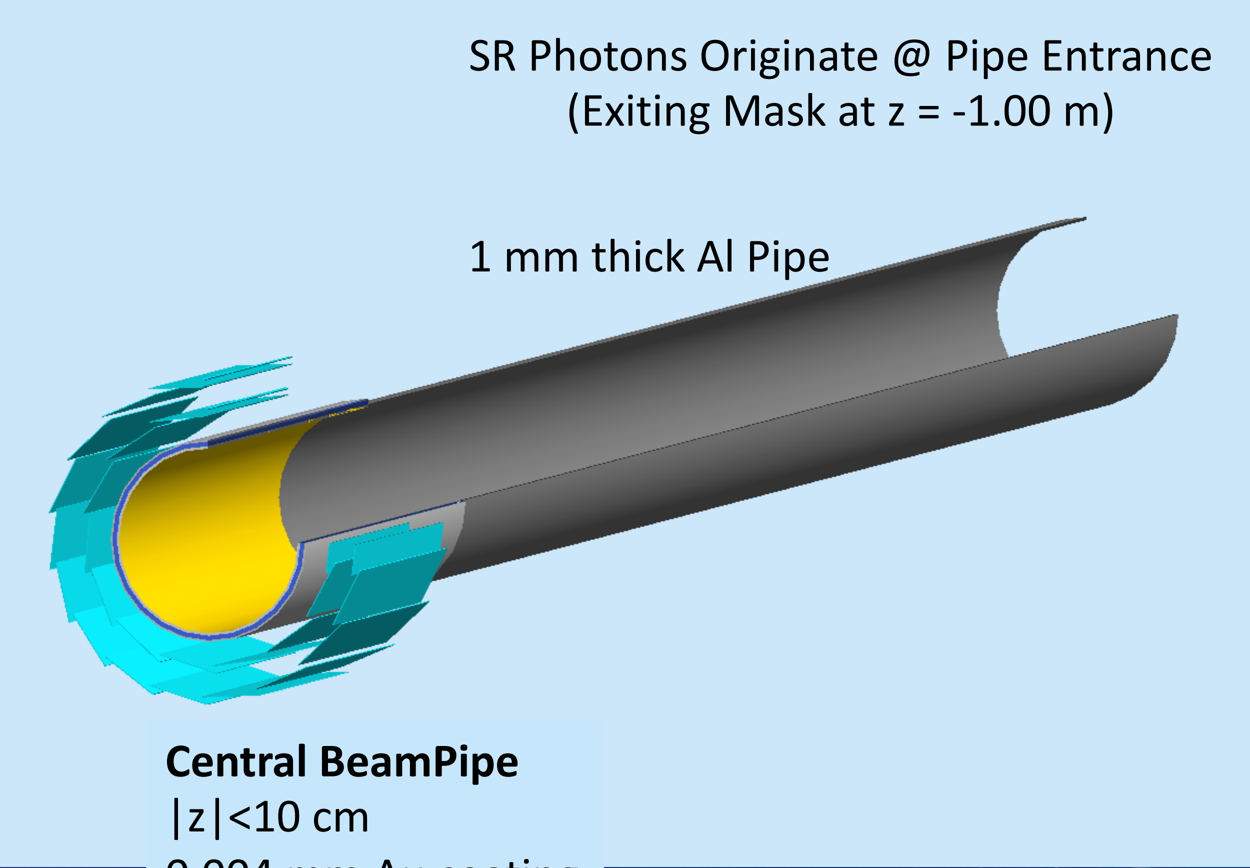


BEAM GAS INTERACTIONS

- Local studies
  - Vacuum in IR region only (±1.5 m upstream of IP)
    - This is the dominant vacuum "bulge"
- Next steps (to be completed by Oct. 2019)
  - Extend to entire ion straight section upstream of IP
    - Include upstream iron yoke of Detector solenoid.
    - Aperture ~16 cm radius (around electron beam) at *z*=-3m.
  - Pavel Degtiarenko & Vitaly Baturin starting on FLUKA simulations
    - Pavel Degtiarenko previously completed site radiation hazard study for 2014 JLEIC design.

SYNCHROTRON RADIATION

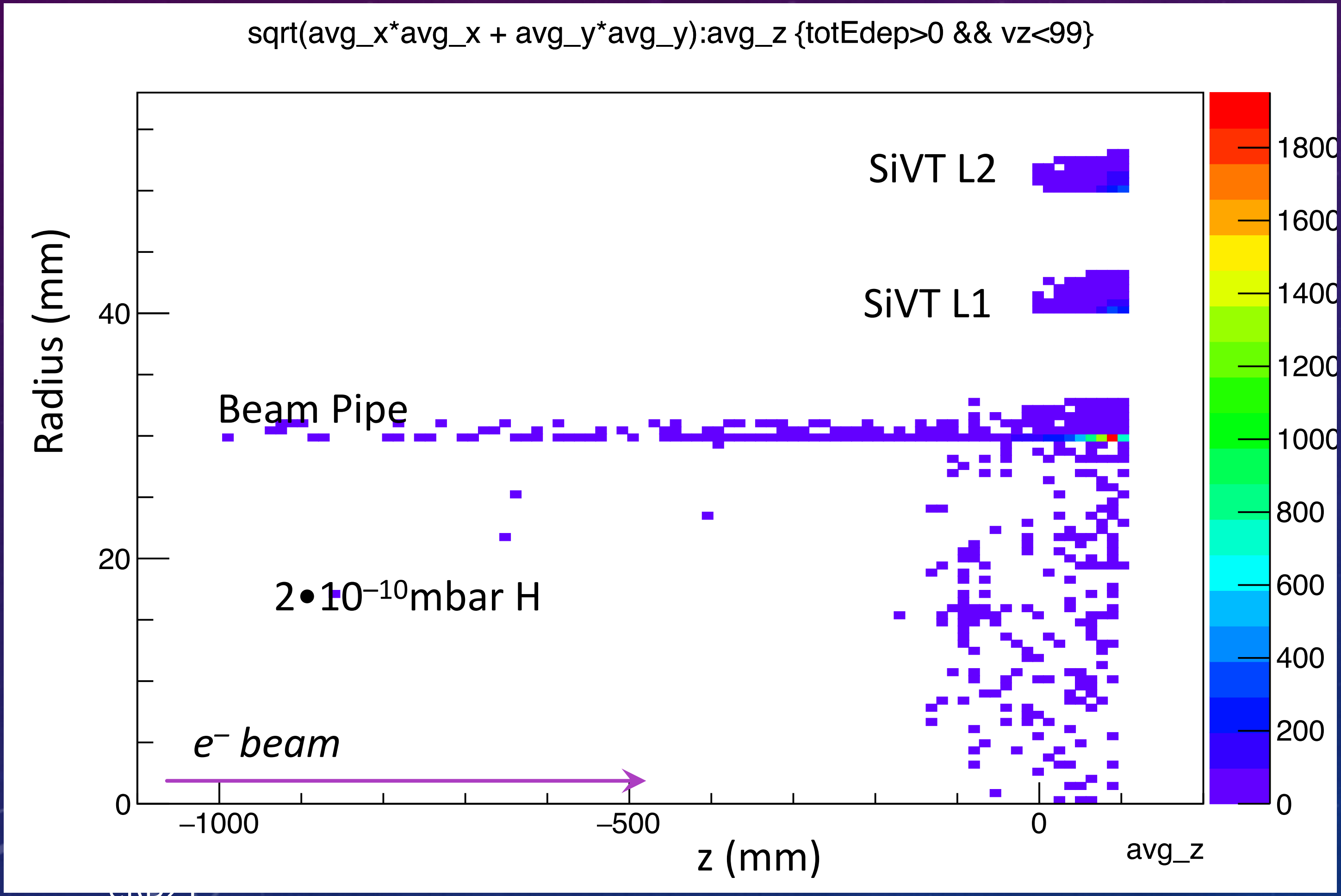
- SR Code ported to JLab
  - Semi-analytic treatment efficiently generates energy flux in 6-dim phase space.
  - After-burner created to convert to statistical ensemble of photons
- Photons passing 12mm radius Cu mask at *z=1*m input to GEANT4
  - 64 mW deposited into walls of central chamber
  - Occupancy in Si Vertex Tracker
  - 1.5 KW in zero degree Total Absorption Calorimeter at ~10 m

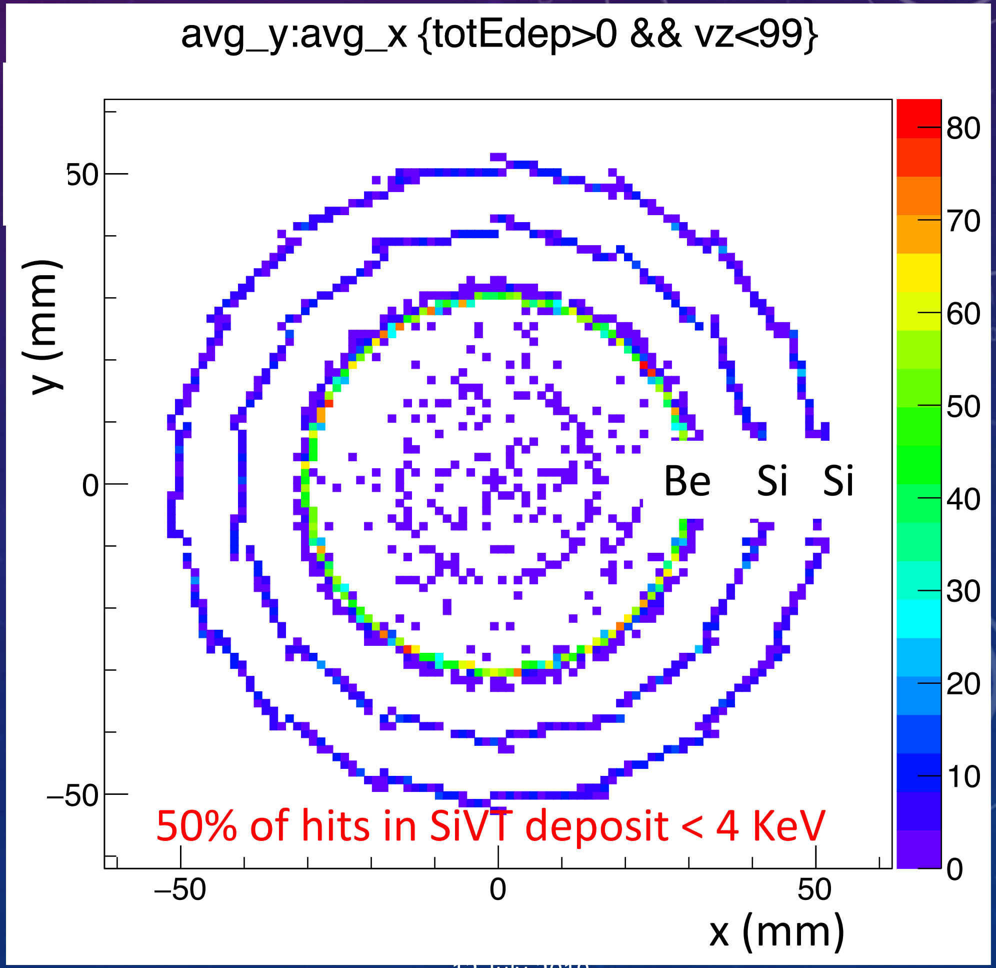


Central BeamPipe
|z|<10 cm
0.004 mm Au coating
0.83 mm Be
1.48 mm H_2O
0.53 mm Be

BEAM PIPE & SILICON VERTEX TRACKER: RAW HITS

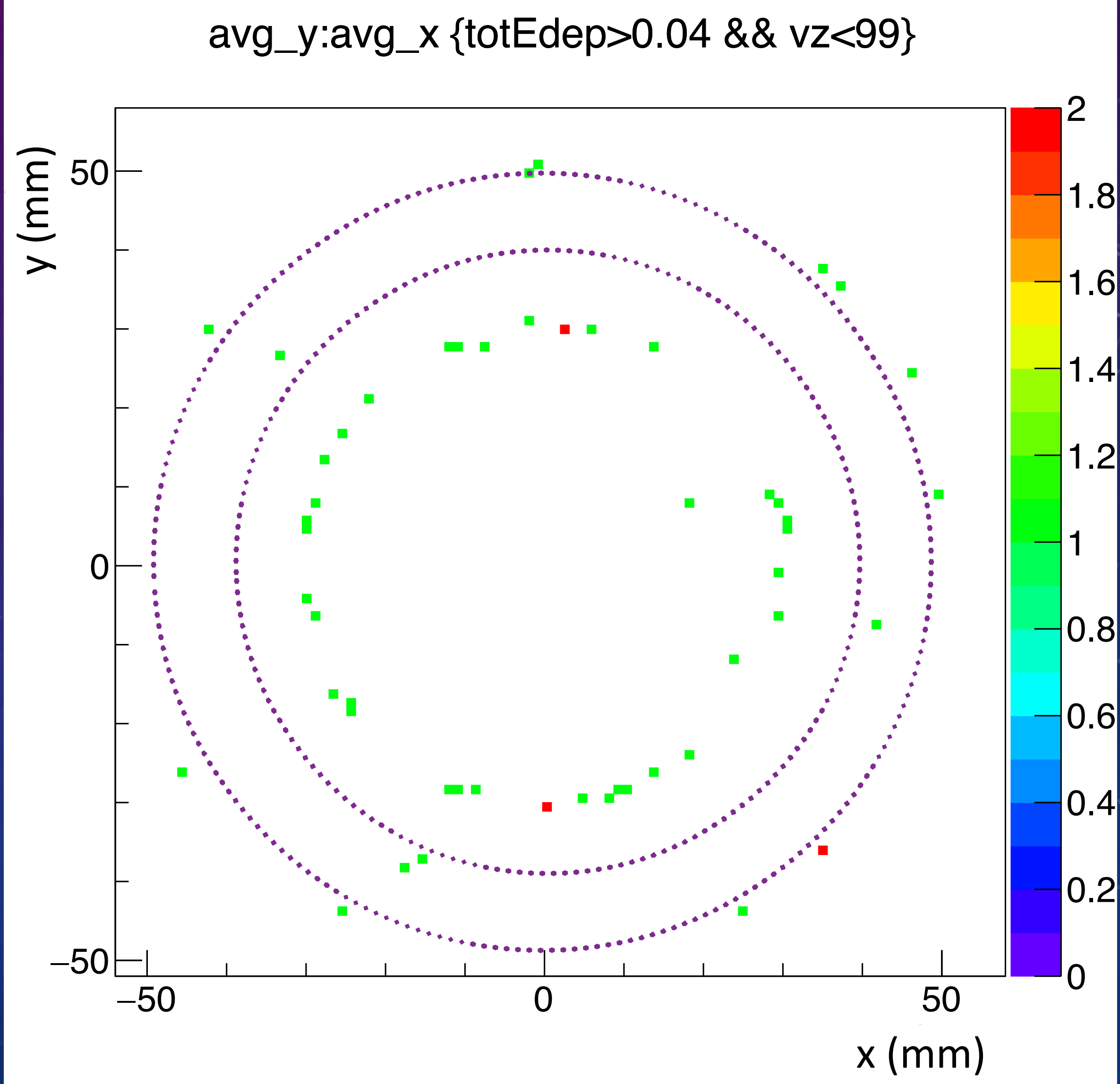
- X-Rays from $5\bullet10^8\, e^-$ *@ 10.5* GeV
- JLEIC: $5\bullet10^9\, e^- / nsec$ *@ 10.5* GeV





BEAM PIPE & SVT: SYNCH RAD HITS ABOVE 40 KEV

- Dotted lines at SVT
- Actual hits higher:
  - Pileup of primary/secondary & multiple photons.
- Next Steps:
  - Compute Pile-up in each SVT channel, accumulated over expected integration time.
  - Add disk SiVT and outer barrel

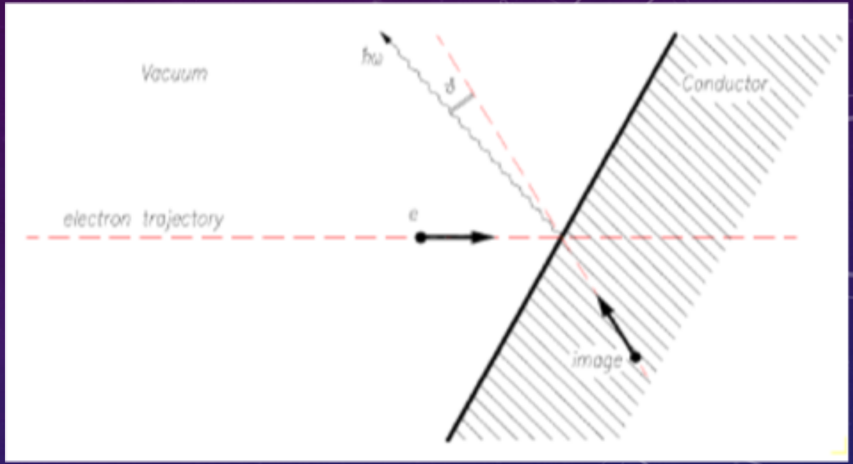


FY20 PROPOSAL

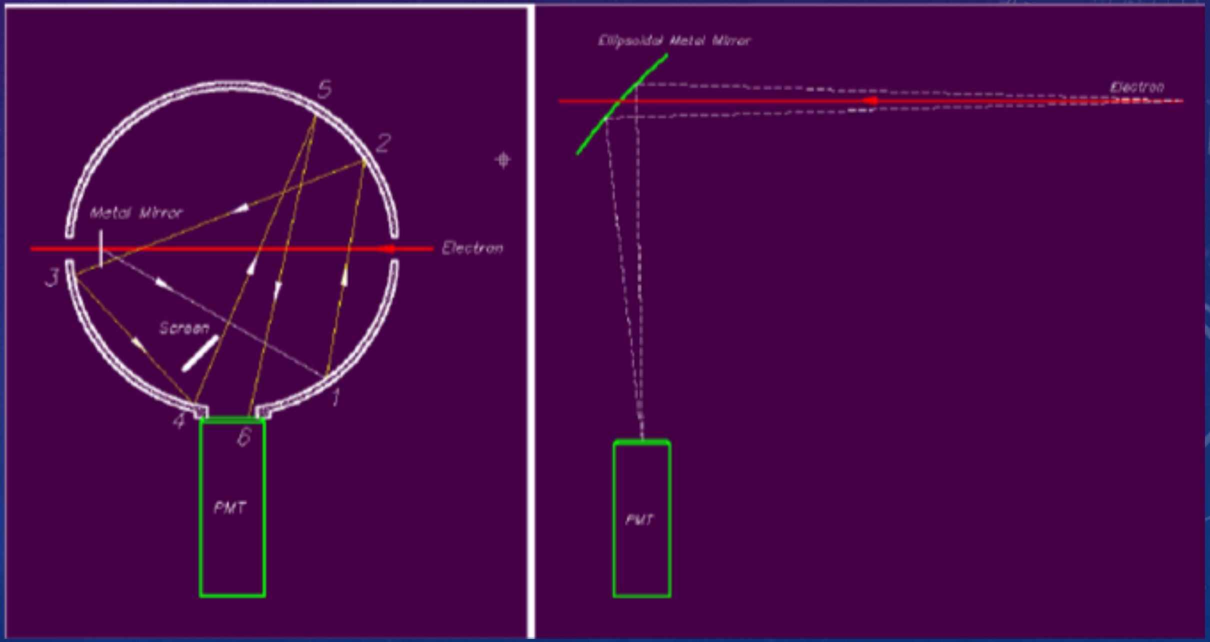
- Background Studies
  - Detector occupancies from synchrotron radiation
    - Normalized to luminosity and channel AREA x INTEGRATION-TIME
    - Beam energy dependence (3-4x more electrons at 5 GeV than 10 GeV)
  - Vacuum design studies
    - Develop engineering design of *in-situ* NEG strips or modules.
  - Beam-Gas Interaction Studies
    - Ion beams
    - Electron beams
    - Neutron studies
- Integration of the EIC Software framework
- Spin-dependent physics (beam-beam) rates
  - Inverse energy weighted cross section = GDH sum rule
- Luminosity Monitor via Optical Transition Radiation (OTR)

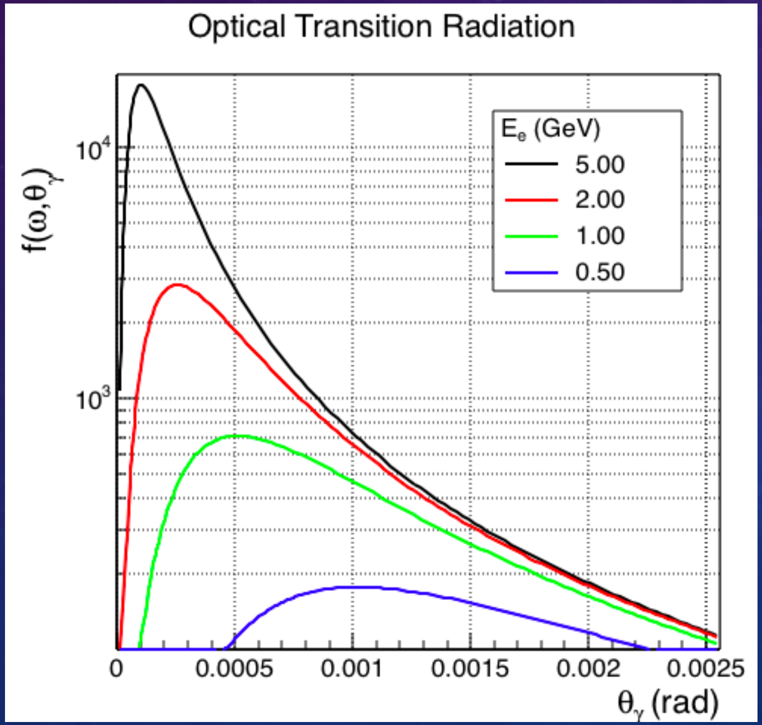
OPTICAL TRANSITION RADIATION

- Emission probability ~ 2% per e^-, e^+
  - Sharply peaked around “reflection angle”
  - Lepton energy from 0 to full e^- beam energy



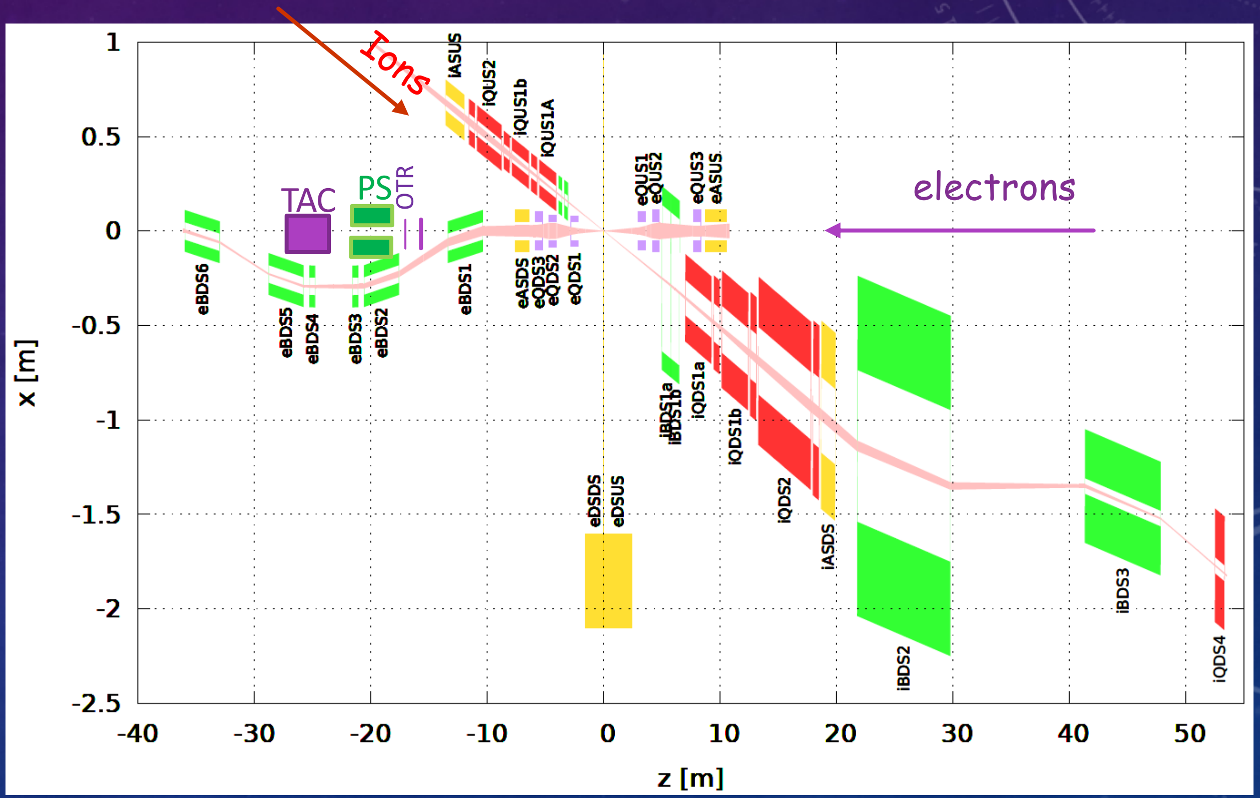
OTR in 0° photon line, between Pair Sp. Convertor and magnet





OTR: POSSIBLE EIC IMPLEMENTATION

- Located in 0° photon line after first dipole of downstream electron chicane
- Backward OTR detection requires thin radiator/mirror between (thicker) $e^{\pm}$ convertor foil, and before PS dipole
- Focusing mirror option
  - Simple, Fast
  - Could monitor bunch-bunch variations (averaged over ~1 min)
- Integrating sphere
  - Possible absolute monitor, but radiation vulnerable.



OPTICAL TRANSITION RADIATION STUDY

- MC simulations
  - Visible light phase space based on $e^{\pm}$ phase space from conversion of bremsstrahlung spectrum
  - Direct backgrounds on phototube
  - Direct backgrounds on integrating sphere
- Prototype
  - Can be tested in JLab Hall D Pair Spectrometer (see also eRD22 TRD)
    - Mirrors:
    - Flat & Focusing,
    - Vacuum chamber,
    - PMT(s),
    - Integrating Sphere,
    - Mounting hardware.

BUDGET: 100% $155K

- 50% Post-Doc (ODU) $51K
  - Beam-Gas Simulations,
  - Neutron thermalization in full accelerator model
- 50% Post-Doc (UConn) $51K
  - Beam-Gas and Synchrotron radiation simulations
  - OTR simulations & Prototype
- Graduate Student (ODU) $25K
  - Spring, Summer 2020:
- OTR Prototype (ODU/JLab) $20K
- Travel (JLab) $8K
  - SLAC—JLab, JLab—BNL

BUDGET REDUCTIONS

- 80% Budget $124K
  - Reduce Post Doc efforts to 45%
  - Reduce Grad Student to summer 2020 only
  - Eliminate integrating sphere from OTR Prototype
  - Reduce Travel
- 60% $93K
  - Post Docs @ 45%
  - Eliminate Grad Student support
  - Eliminate OTR Prototype

SUMMARY

- **All FY19 tasks are completed or being finalized and documented on track to complete the project deliverables by October first 2019**
- **Strong team of nuclear and accelerator scientists and engineers in place**
- **Ready to perform detailed rates and occupancies due to different background sources to assist optimization of detector, associated electronics, beam-profile and beam pipe as design changes**
- **Ready to incorporate our work into EIC framework**

- **We request FY20 funding to perform detailed simulations of the EIC machine related background for both JLEIC and eRICH configurations:**
    - Synchrotron radiation modeling code
    - Static & dynamic vacuum modeling
    - Neutron flux
    - Optical Transition Radiation monitor

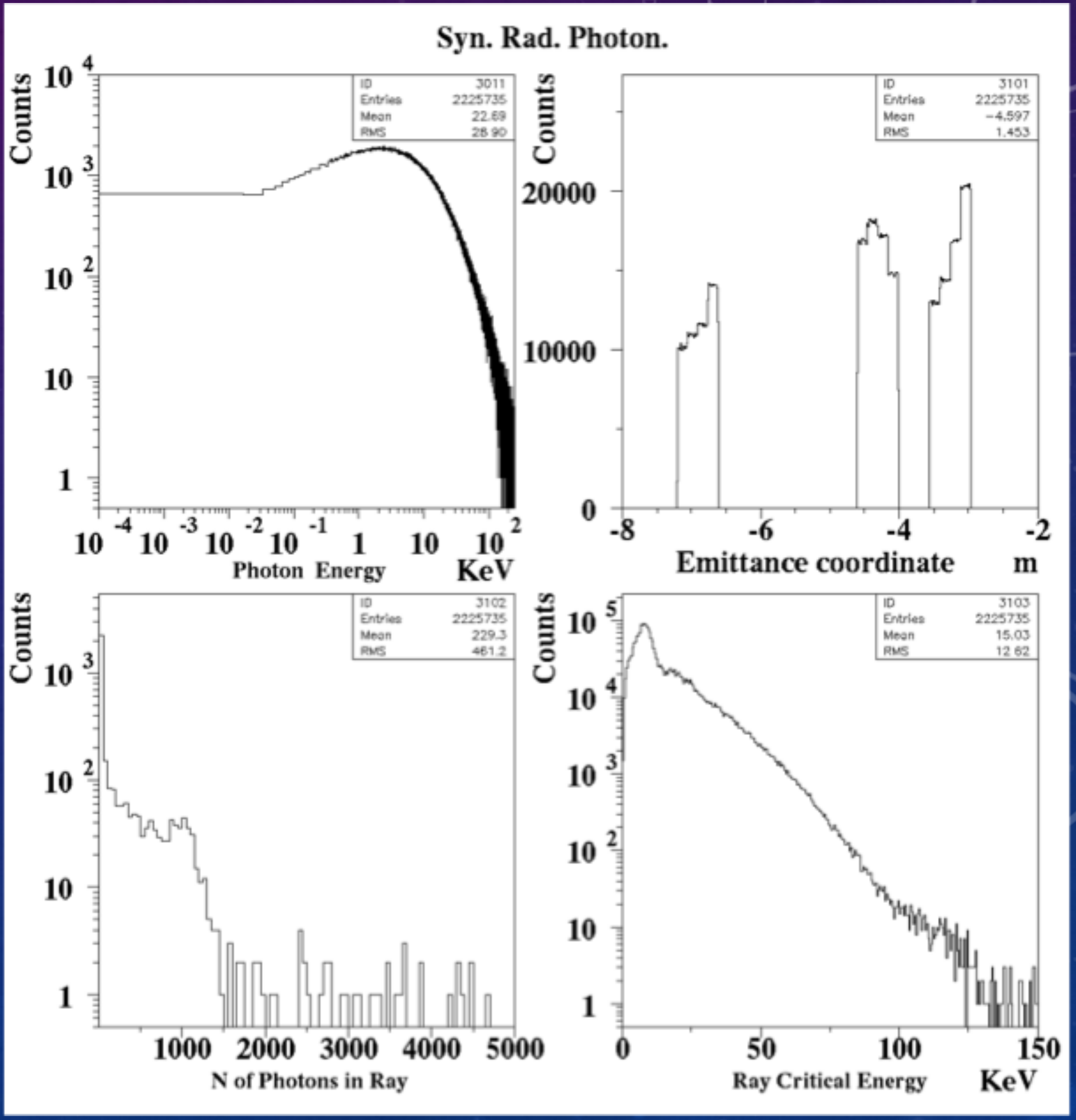
1. WHAT SOFTWARE TOOLS ARE CURRENTLY MISSING AND IMPEDE YOUR PROGRESS IN DETECTOR DEVELOPMENT EFFORT?

- **FY19 limitations**
  - Only Mike Sullivan from SLAC was able to run SR Code
  - Problem resolved, SR Code is now ported to JLab and we are making it user-friendly and publicly accessible
- **Resources from FY20 if fully funded will allow**
  - Implement the design and Fluka and Geant3: the tools exist we need just resources to perform the systematic studies, this is of particular importance for neutron background studies: This was not possible in FY19 due the funding limitation.
- **Software Requirement for next stages**
  - **Alex Kiselev will guide us in use of EIC_ROOT, or other eRHIC-centric tools**
  - Will work with JLEIC software team.
  - A more clearly standardized and unified framework for running, modifying, analysis and reconstruction simulations would be an enormous benefit

…AND MORE…

SYNCHROTRON RADIATION FLUX FROM FFQ

- Synrad code ported to Jlab.
  - Synchrotron radiation per 10^{10} electrons (including beam tail).
  - Updating/improving user interface
- Post-processor to generate “Lund file” of photons for input to GEANT4.



GLOBAL PHYSICS RATES

- Total $ep \rightarrow X$ hadron production dominated by photo-production (~0° electron scattering)
- Rate = $\mathcal{L}_{ep} \int_{Th}^{s} dW^2 \int dQ^2 \frac{d^2\Gamma}{dW^2 dQ^2} \sigma_\gamma(W^2)$
- Rate $\rightarrow \mathcal{L}_{ep} \int_{Th}^{s} dW^2 \frac{t^V(W^2, Q^2_{Max})}{W^2 - M^2} \sigma_\gamma(W^2)$
  - $t^V = \frac{\alpha}{\pi} ln\left[\frac{Q^2_{Max}}{Q^2(0°)}\right]\left(1 - y + \frac{1}{2}y^2\right)$ $\quad y \rightarrow \frac{W^2 - M^2}{s - M^2}$
  - t^V: weak dependence on $Q^2_{Max},\ W^2,\ s.$
- Integrating over empirical γp cross section
  - Total hadron production rate at 3x200 GeV^2 ($\mathcal{L}$=10^{34}/cm^2/sec) = 0.5 MHz
    - Scales ~ ln(s_{ep}/Threshold)

PHYSICS RATES e+A

- R(eA) ~ Z•R(ep) + N•R(en) + Giant Dipole Resonance
  - Semi exact formula for 1/energy weighted integral over GDR
  - Results for January 2020

OTR: ANGLE INTEGRATED FLUX

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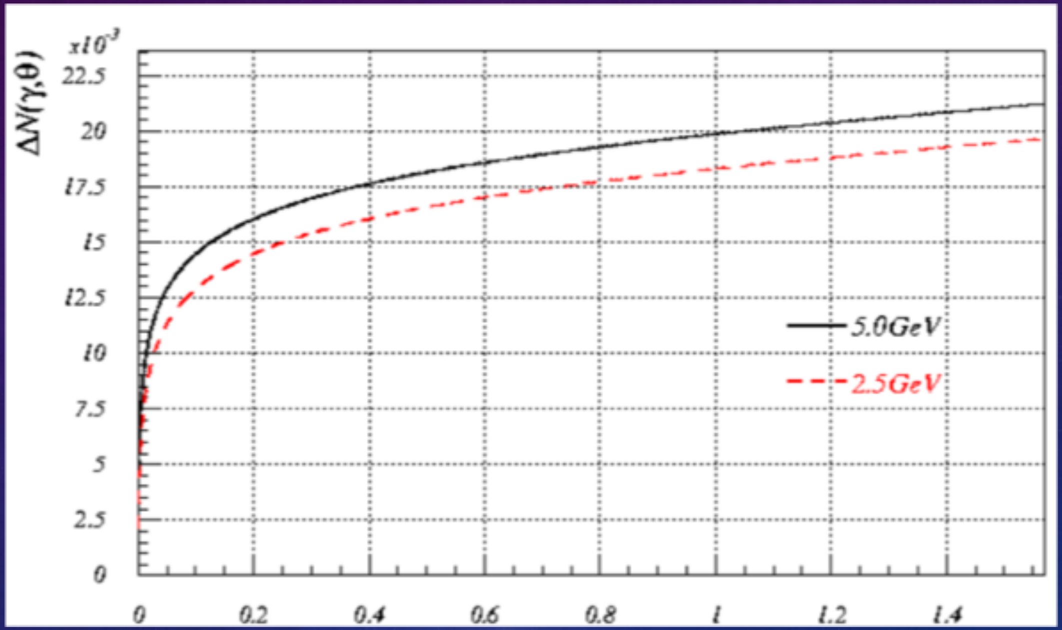

Integration angle (rad)

2% per incident electron

OTR RATE

- Integrated bremsstrahlung flux
  - 0 to 2 mrad; and
  - 2 to 4 mrad
- With a $X/X_0 = 1\%$ radiator:
  - Approx 1000 optical photons (350-450 nm) per sec with 10 GeV electron beam and $\mathcal{L}=10^{33}/cm^2/sec$
    - 1% Lumi measurement in 1 min
    - 1% Lumi measurement per bunch in 1 hour